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## Incentives and Shortages in the Soviet Economy: A Model of a Three-Level Hierarchy

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Incentives and Shortages in the Soviet Economy:  
A Model of a Three-Level Hierarchy

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## Abstract

We give a model of hierachial planning which yields excessive supply disruptions causing low factor productivity at equilibrium. The model closely fits the basic institutional features of Soviet-type economies.

## INCENTIVES AND SHORTAGES IN THE SOVIET ECONOMY: A MODEL OF A THREE-LEVEL HIERARCHY

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It is now widely recognized that one of the most serious problems of Centrally Planned Economies is the shortage of inputs or more generally unreliability of supplier behavior.<sup>1</sup> Supplies typically don't arrive on time, and even when they do, they often turn out to be not quite what they were supposed to have been. Even more strikingly, this seems to happen even when aggregate statistics show that aggregate plan targets for the production of those particular goods have been met.

The connection between this phenomenon and other disfunctional aspects of these economies like input hoarding and quality deterioration have been recognized for quite some time now (for an early study of the Soviet system from this point of view, see Berliner (1957)). But the problem does not seem to have been alleviated since then and Alec Nove was writing in 1983 that:

"There is an increasing feeling among Soviet economists themselves that drastic changes are essential. It is not just that growth has slowed down, that plans are not fulfilled. Shortages have become more serious, disequilibria and imbalances, which have always existed, have reached intolerable levels, and by intolerable I mean that the leadership itself is alarmed and is not prepared to tolerate them (though it has yet to devise a cure)" [Nove, 1983].

The problem is therefore both serious and apparently insoluble. Our aim in this paper is to suggest a systemic explanation of this phenomenon in a model of the principal-agent type.

There have been earlier attempts to explain this phenomenon in the principal-agent type framework (see for example Keren (1972) and Moore (1974)). However, these studies limit themselves to showing that if there is asymmetric information between the central planner and the person who directly controls production it may be optimal for the central planner to give out production targets which cannot always be met.<sup>2</sup> This is certainly true but it does not explain why this leads to such devastating consequences for centrally

planned economies. After all, asymmetric information between the principal and the agent in the production sector is also a characteristic of capitalist economies.

Our analysis, by contrast, takes as its starting point a number of (stylized) institutional features of existing centrally planned economies.<sup>3</sup> These are:

- F1: That firms in centrally planned systems are directly controlled by ministers and not by the central planning body;
- F2: Each ministry controls the production of a very large number of goods especially considering the fact that in general goods produced at different locations or at different times are not going to be perfect substitutes;
- F3: The central planner controls the ministers by a system of rewards and punishments. These rewards (and punishments) are decided on the basis of the performance of ministers according to certain aggregate statistics like the total output of a certain product;
- F4: The allocation system is quite rigid in the sense that normally buyers are only allowed to buy from a few fixed sources of supply.

The thesis of this paper is that F1 to F4 along with the fact that the central planner cannot directly observe the production decisions taken by ministers can explain the kind of supply behavior found in these countries.

The logic of our explanation is best understood by considering the example of a hypothetical ice cream plant. The plant produces ice cream using milk and fresh fruits. Since both these ingredients are highly perishable the plant needs to have the right combination of milk and fruits at the right time. If the milk supplier is erratic and not well coordinated with the supply of fruits lots of milk and fruits will be wasted. This will be especially true



if, along the lines of our stylized fact F4, the manager of the ice cream plant cannot at the spur of the moment go out and find alternative sources of milk.

Under these circumstances the central planner would very much like to make sure that the minister controlling milk supplies makes all his deliveries on schedule. However it is quite reasonable to assume along the lines of our stylized fact F3 that the minister's rewards depend only on how much he supplies in a month. Now we know that even if daily supplies from the milk ministry are quite erratic a lot of the variation will cancel out in the course of a month and the minister controlling the milk industry may easily succeed in meeting his monthly targets. In this case he will have no incentive to control the variations in the daily supplies of his ministry. Output of ice cream will be below the socially optimal level even if the monthly production of milk and fruits meets the planned targets for those two goods.

The example we have chosen to discuss above is certainly somewhat special since most other intermediate goods are not as perishable as milk and fresh fruits. On the other hand the general logic of the argument only depends on the fact that the accounting system (and the system of rewards based on it) does not distinguish between a number of products which are not perfect substitutes. If this was the case the agents (say the ministers) controlling this group of products will not pay sufficient attention to controlling the variations in each component of the group which is lumped together (since the variations cancel out). However from the point of view of the firms using the goods produced by these firms as inputs this variation will be quite costly since they will typically have strictly concave production functions. From the social point of view the result will be excessive variability in the supplies of inputs and a lowered productivity of the final goods.

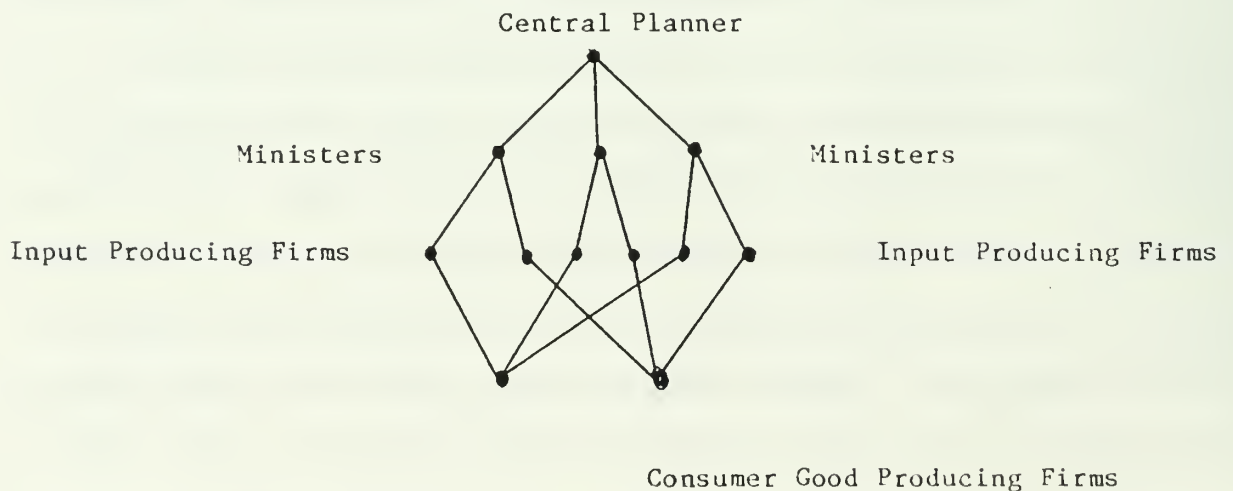
In Section II of this paper, we introduce a simple model which formalizes the ideas discussed above. In Section III, we formally establish the results described above. We find that even in the case where a minister controls only a finite number of firms, our results continue to hold but only as long as we can prevent large punishments of ministers.

Section IV of the paper looks at the rationale for using the framework we use. In particular, we discuss the foundation for using F1 to F4 in our model. We discuss some empirical justifications but more importantly, also look at whether we can expect these features to be altered significantly in the near future. We argue that these features are in fact closely connected with certain fundamental characteristics of centrally planned economies and therefore are deep-seated characteristics of the system.

We conclude in Section V with some discussion of related work.

## II

### The Model



The above diagram illustrates the structure of our very stylized model of centrally planned economies. The central planner does not directly control any firms but is interested only in maximizing the total output of consumer

goods producing firms  $\sum_{m=1}^M C_m$ . The production of consumer good  $m$  uses  $N$  inputs  $X_{m1}, \dots, X_{mN}$ . The production function for consumer goods in each firm is assumed to be  $C_m(X_{m1}, \dots, X_{mN})$ . Each input that is used in the consumer good industry is produced by a separate input producing firm controlled directly by a minister who controls all the firms producing that particular type of input.

### The Ministers

So far we have not said anything about the minister's preferences or his controlling activity. Actually we can allow a variety of controlling actions by the minister; he could be choosing the technologies that the firms under him use, setting incentive schemes for the managers of these firms or determining how closely he would monitor the firms. Given any action,  $a_n \in A_n$ , by the  $n^{\text{th}}$  minister, the manager and other agents in each firm will respond optimally and generate a (random) output  $X_{mn} = X_{mn}(a_n, U_{mn})$ .  $U_{mn}$  is the shock to the  $m^{\text{th}}$  product of the  $n^{\text{th}}$  minister.

We assume that the minister has to put in a certain level of effort to implement each of these actions and the level of effort  $V$  varies with the action chosen:  $V = V(a_n)$ . For some of the results in this paper, we will not need to specify anything more about the relation between the  $X_{mn}(\ )$  function and the  $V(\ )$  function. However in interpreting the results, it will be useful to keep in mind the following structure: imagine the case where the  $C_m(\ )$  function is of the quadratic type so that only the first two moments of the random variables  $X_{mn}$  will matter for determining the output of the consumption good.

Now, if we take  $a$  to represent the mean of  $X_{mn}$  and  $s$  to represent its variance, we define a 'production possibility frontier' for the minister in terms of his effort and the mean and variance it generates as  $H(a, s, V)$  with

$H_1 > 0$ ,  $H_2 < 0$  and  $H_3 < 0$ . Less formally, we assume that the minister can increase the mean output of each of his firms or reduce the variance of their output by choosing an action that requires a higher effort. This will be the case for example if the ministers' choice variable is the amount of monitoring effort he puts in. If he spends more effort on monitoring, he could make his firms produce more or produce more reliably.

### Structural Assumptions

In the rest of this section, we will make a number of structural assumptions which we use to get our results.

- A1: Each consumer good producing firm is supplied by only one firm producing each type of input and each input producing firm supplies to only one consumer good producing firm. This assumption essentially embodies our stylized fact F4.
- A2: The outputs of all the firms controlled by each minister have identical and independently distributed random variables with finite mean and variance.
- A3: The rewards function for each ministry is a Borel measurable increasing function of  $\sum_{m=1}^M X_m$ , bounded above and below by numbers  $\bar{B}$  and  $\underline{B}$  respectively. A part of this assumption embodies our stylized fact F3. The assumption that the function is increasing would follow if the minister has free disposal of output.
- A4: The set of actions available to the minister,  $A_n$ , is finite.

### The Central Planner's Problem

Under the assumptions we have made for a given size of the ministry,  $M$ , and a given number of ministers,  $N$ , the central planners' problem reduces to a



simple principal-agent problem (with multiple agents) between the central planner and the ministers.

The central planner maximizes

$$\begin{aligned}
 W &= \text{Exp}[C - \sum_{h=1}^N R_n] \text{ subject to} \\
 C &= \sum_{m=1}^M C_m \\
 C_m &= C_m(X_{m1}, \dots, X_{mN}) \quad m = 1, \dots, M \\
 R_{mn} &= R_{mn}(\sum_{m=1}^M X_{mn}) \quad n = 1, \dots, N \\
 X_{mn} &= X_{mn}(a_n^*, U_{mn}) \quad m = 1, \dots, M, \text{ and } n = 1, \dots, N
 \end{aligned}$$

and,

$$\text{Exp}[h(R_n) - V(a_n^*)] \geq U_{\min}$$

where,

$$a_n^* = \arg \max_{A_n} \text{Exp}[h(R_n) - v(a_n)].$$

$V(a_n)$  represents the ministers' disutility of taking that particular action  $a_n$ .  $h(\cdot)$  represents the ministers utility from the reward, and  $U_{\min}$  represents the minimum utility that has to be guaranteed to the ministers.

The choice of this very simple structure for our model is influenced by a desire for clarity and specificity of presentation. However within this rather restrictive structure we can allow for several different interpretations of our assumptions and therefore encompass many different aspects of the problem. For example the different consumption good producing firms in our model may be consistently interpreted as the same firm at different points of time (this would be along the lines of our ice cream factory illustration). On the other

hand the ministries which are assumed to be producing only one good could be thought of as being just a subdivision of a ministry producing that particular good. Alternately one can think of each ministry as producing a number of different goods which all belong to the same general category (different types of ball-bearings for example).

### The Large Hierarchy

We have already said that the results in this paper rely on looking at a case where the minister controls a very large number of very small firms (actually these could just be divisions of firms producing slightly different products). In formalizing this idea, we actually look at a sequence of production structures where the firms under each minister get smaller and more numerous but otherwise remain identical. This idea is presented formally below.

Define  $\tilde{X}_{mn}(a_n)$  to represent the random variable  $X_{mn}(a_n, U_{mn})$ . Then formally, a hierarchy will be given by

$$H = \{N, M, A_1, \dots, A_N, \tilde{X}_{11}, \dots, \tilde{X}_{M1}, \tilde{X}_{12}, \dots, \tilde{X}_{mn}, \dots, \tilde{X}_{MN}, V, R_1, \dots, R_N, C\}.$$

The utility of the central planner is always taken to be the total output of the final good minus payments to the ministries so it is not specified here.

A simple hierarchy is one in which  $M = 1$ . Given a simple hierarchy  $H$ , the infinite sequence of hierarchies generated by  $H$  is given by  $\{H_M\}_{M=1}^{\infty}$  where,

$$1) \quad H_1 = H$$

$$2) \quad H_M = \{N, M, A_1, \dots, A_N, \tilde{X}_{11}, \dots, \tilde{X}_{MN}, V, R_1, \dots, R_N, C^M\}$$

$$3) \quad \tilde{X}_{mn}(a_n) \text{ has the same distribution as } \frac{\tilde{X}_{1n}(a_n)}{M} \text{ in}$$

hierarchy H for each  $a_n \in A_n$  for  $n = 1, \dots, N$  and  $m = 1, \dots, M$

$$4) \quad C^M(X_{m1}, \dots, X_{mN}) = C(X_{m1}^M, \dots, X_{mN}^M)/M.$$

As should be evident, the organizing principle of this construction is to ensure that while the number of firms increases the expected output of each ministry remains the same.\*

Since for the rest of the paper we will look at the relation between the central planner and a single ministry, we can simplify notation a little and drop the subscript. Further, let us introduce the notation  $\tilde{X}(a)$  to represent the random variable  $\tilde{X}_1(a)$  in the simple hierarchy.

In the next section, we will study the structural properties of this model.

### III

#### Analysis of the Model

One can directly consider the principal-agent game written out above and try to say something about the nature of the second best outcome. However, we chose to proceed in a somewhat indirect way. We first characterize the nature of the implementable set under the assumption that a minister controls a large number of firms. Then using this characterization, we try to say something about the second best outcome in a somewhat more specific principal-agent game.

Theorem 1 tells us what will not be in the implementable set. Following on that, Theorem 2 tells us what will be in that set.

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\*In the rest of the paper as M varies, everything varies as in the above sequence.

It is convenient to introduce the notation  $a_1 >_R a_2$  to denote  $a_1 \in A$  is preferred to  $a_2 \in A$  by the ministry faced with a reward function  $R$ . Of course this preference relation will depend on  $M$ .

Theorem 1: Suppose, A2, A3 and A4 hold. Consider  $q$  actions  $a_1, \dots, a_K, \dots, a_q$  for the ministry. Suppose  $V(a_1) < \dots < V(a_q)$  and,  $E(\tilde{X}(a_1)) > \dots > E(\tilde{X}(a_K)) > \dots > E(\tilde{X}(a_q))$ . Then there exists  $M^*$  such that  $M > M^*$  implies  $a_1 >_R \dots >_R a_q$  for any  $R$ .

Proof: It is sufficient to prove the statement for  $a_1$  and  $a_2$ . Choose a  $\delta > 0$  and an  $\epsilon > 0$  such that

$$\epsilon < \frac{E(\tilde{X}(a_1)) - E(\tilde{X}(a_2))}{2}.$$

The weak law of large numbers implies that there exists  $M^*$  such that  $M > M^*$  implies

$$P\left\{\left|\sum_{m=1}^M \tilde{X}(a_1) - E(\tilde{X}(a_1))\right| > \epsilon\right\} < \delta \text{ and}$$

$$P\left\{\left|\sum_{m=1}^M \tilde{X}(a_2) - E(\tilde{X}(a_2))\right| > \epsilon\right\} < \delta.$$

This means that,

$$E(h(R(\sum_{m=1}^M \tilde{X}_m(a_2)))) - E(h(R(\sum_{m=1}^M \tilde{X}_m(a_1)))) < \delta(h(\overline{B}) - h(\underline{B})),$$

which can be made arbitrarily small. Since  $V(a_1) < V(a_2)$ , the result is proved.  $\Delta$

In other words for a large enough size of the hierarchy, the implementable set cannot contain any action that is dominated in the sense that there exists another action which generates a higher mean output for each firm and requires no greater effort.



This above result of course simply formalizes the basic intuition we provide in the introduction. The next result basically tells us that this simple intuition cannot carry us any further.

Call  $A'$  the set of undominated actions on  $A$ , i.e., let  $a_1 \in A'$  iff  $a_1 \in A$  and  $\nexists a_2 \in A$  such that  $V(a_1) \geq V(a_2)$  and  $E(\tilde{X}_m(a_1)) \leq E(\tilde{X}_m(a_2))$  with one inequality strict. Then we prove:

Theorem 2: Suppose that  $A'$  does not contain two actions with equal mean and effort. Then under assumptions A3 and A4 there exists  $M^*$  such that  $M > M^*$  implies that for each  $a \in A'$  there exists  $R$  that implements  $a$  at an expected cost of no more than  $\bar{t}$  as long as the utility to the minister of taking action  $a$  and receiving  $\bar{t}$  for sure is higher than the utility of taking his least effort action and receiving  $\underline{B}$  for sure, and  $a$  and  $\bar{t}$  give the minister utility greater than  $\bar{U}_{\min}$ .

Proof: Choose  $a \in A'$  and  $\epsilon > 0$ . Make sure  $\epsilon$  is small enough so that if  $E\tilde{X}(a') < EX(a)$  then  $\epsilon < EX(a) - E\tilde{X}(a')$  for each  $a' \in A'$ . Set

$$R(X) = \bar{t} \text{ if } X \geq EX(a) - \epsilon \\ = \underline{B} \text{ otherwise.}$$

If  $M$  is large enough any action  $a'$  with  $E\tilde{X}(a') < EX(a)$  will lead to a money payoff of  $\underline{B}$  with probability arbitrarily close to one while  $a$  will lead to  $\bar{t}$  with probability arbitrarily close to one. We have assumed that the effort saved cannot compensate for this money loss so  $a \succ_R a'$  for large enough  $M$ .

Take an  $a' \in A'$  with  $E(\tilde{X})(a') > EX(a)$ . Since  $a \in A'$ ,  $V(a) < V(a')$ . For a large enough  $M$  the money payoff from either  $a$  or  $a'$  will be arbitrarily close to  $\bar{t}$ . So  $a \succ_R a'$  since  $a$  requires less effort.  $\Delta$

As it is easy to see, these results already tell us something about the attainability of the first best which for emphasis we state as a proposition.

Theorem 3: If, at the first best, it is possible to achieve the same (or a greater) expected output for each firm with less effort (but presumably greater variability of firm output) then the first best is not implementable for a large enough size of the ministry.

The conditions under which this proposition holds are quite weak. In terms of the formulation introduced in Section II (see p.4), it is sufficient for this proposition that  $H(m,s,v)$  is differentiable at the first best.

We have, however, not yet said anything about why the hypothesis of Theorem 3 should hold. The example given below addresses this question. Before we look at the example however it will be useful to try to understand why we should expect the hypothesis of Theorem 3 to hold. Theorem 1 tells us that given a large hierarchy the minister will essentially care only about his own effort and the expected output of his ministry. Given that the  $C(\quad)$  functions are strictly concave and given our allocative assumption A1 the output of the consumption goods industries would however depend on the entire distribution of production of the input industries and not just the expectation. Therefore in the first best the minister should take into account moments of the distribution of output of the firms on his industry other than the mean. One would therefore expect that at the first best the minister will find it possible to trade off socially less desirable values of the higher moments for a lower effort, keeping the expected output the same. The first best will therefore not be implementable.

This however does not prove that the second best outcome would have excessive input production variability. As we have shown, everything that is

undominated is implementable. Clearly there will be options which have a lower mean output and less output variance than the first best but which also involve less effort and therefore are undominated.

The example below sheds some light on when the second best outcome will be more variable than the first best.

### Example

Consider the following economy.

1. Production function of the final good

$$C = \sum_{i=1}^N a_i x_i - \sum_{i=1}^N b_i x_i^2$$

where  $x_i$  is the amount of the  $i^{\text{th}}$  input.

2. The central planner wants to maximize  $E(C)$ , i.e., the mathematical expectation of  $C$ .
3. Each minister's "production" function is given by the following indirect relationship

$$V(\bar{x}_i, \sigma_i^2) = \bar{x}_i^2 + (\sigma_i^2 - \sigma_i^{*2}(\bar{x}_i))^2.$$

Here  $\bar{x}_i$  and  $\sigma_i^2$  are the mean and variance of the output distribution generated in each firm controlled by the minister,  $V$  is the effort the minister puts in to generate this mean and variance and  $\sigma_i^{*2}(\bar{x}_i)$  is the maximum variance option available for that level of  $\bar{x}_i$ , with

$$\frac{d\sigma_i^{*2}(\bar{x}_i)}{d\bar{x}_i} \text{ having either sign but with } \frac{d^2\sigma_i^{*2}(\bar{x}_i)}{d\bar{x}_i^2} > 0.$$

4. We look at the limit of the sequence of hierarchies defined above so that each minister essentially controls an infinite number of infinitesimal firms. The aggregate output of the minister will therefore be  $\bar{x}_i$  and his

reward (given that random incentive schemes can be ruled out) will be a deterministic amount  $R$ .

5. We assume that the ministers maximize a utility function of the form

$$\sqrt{R} - V(\bar{x}_i, \sigma_i^2).$$

In this model in the first best situation, the central planner chooses  $\sigma_i^2$ ,  $\bar{x}_i$  and  $R_i$  for each  $i$  to maximize

$$\Sigma a_i \bar{x}_i - \Sigma b_i (\sigma_i^{*2} + \bar{x}_i^2) - \Sigma R_i$$

subject to  $\sqrt{R_i} - (\bar{x}_i^2 + (\sigma_i^{*2} - \sigma_i^2)^2) - U_{\min} = 0 \forall i$ . The conditions for maximization yield, for all  $i$

$$J(\bar{x}_i) = 4\bar{x}_i^3 + [2b_i + 4(\sigma_i^{*2} - \sigma_i^2)^2 + 4U_{\min}] \bar{x}_i + b_i \frac{d\sigma_i^{*2}}{d\bar{x}_i} - a_i = 0.$$

By contrast, in the second best case, the minister will always choose the option that generates the highest variance for a given mean output level to minimize effort. Given this, the central planner chooses  $\bar{x}_i$  and  $R_i$  for each  $i$  to maximize

$$\Sigma a_i \bar{x}_i - \Sigma b_i (\sigma_i^{*2} + \bar{x}_i^2) - \Sigma R_i$$

subject to  $\sqrt{R_i} - \bar{x}_i^2 - U_{\min} = 0$  for each  $i$  which yields,

$$H(\bar{x}_i) = 4\bar{x}_i^3 + [2b_i + 4U_{\min}] \bar{x}_i + 2b_i \frac{d\sigma_i^{*2}}{d\bar{x}_i} - a_i = 0 \forall i.$$

Notice also from the first order condition for the first best problem that

$$\sigma_i^{*2} - \sigma_i^2 = \frac{b}{4(\bar{x}_i^2 + (\sigma_i^{*2} - \sigma_i^2)^2 + U_{\min})} > 0$$

which already tells us that the first best and the second best do not coincide. Further, it is evident that the second best outcome,  $x_{is}$  (given by the



solution to  $H(x_i) = 0$ ) for that particular value of  $i$  will be greater than the first best outcome  $\bar{x}_{if}$  (given by the solution to  $J(\bar{x}_i) = 0$ ) unless  $\frac{d\sigma^{*2}(\bar{x}_i)}{d\bar{x}_i}$  is large and positive.

Thus, we have shown that in our example, under the assumption that  $\frac{d\sigma^{*2}_i}{d\bar{x}_i}$  is not a large positive number the second best outcome will display a larger mean and a larger variance of individual firm output than the first best outcome. While we do not prove here that this result in more general contexts, our example is relatively general<sup>4</sup> and shows that it is quite possible in this framework to generate outcomes in which a high aggregate output of the input is accompanied by a highly unreliable supply of it which is exactly what we had set out to explain.

We now present a number of comments about the results in this section.

1. The results above can easily be extended to allow for infinite but compact action spaces as we show in Banerjee-Spagat (1988).
2. The assumption of independence between the outputs of individual firms is not necessary. We prove the same results allowing for correlation between outputs of firms in Banerjee-Spagat (1986).
3. Allowing negative correlation between outputs of firms actually aggravates this problem. This can be seen best where the minister controls two firms whose outputs are perfectly negatively correlated so that the total output of the two firms will not vary. The minister who controls the two firms will therefore not care about the extent of variability of the output of the two individual firms. (This case is discussed in greater detail as Example B in Banerjee-Spagat, 1986.)
4. There might be some question about why we prove the results in this paper using the finite hierarchy case instead of dealing directly with

the simpler infinite approximation. Our response to this is that the role of bounded punishments cannot be understood except by considering the finite case. In the limiting infinite hierarchy since the aggregate ministry output is deterministic, Theorem 1 holds even without a bound on punishments. However, if we allow for unbounded punishments in the finite hierarchy case the limit of the sequence of second best outcomes as the size of the hierarchy goes to infinity may be the first best outcome. The intuition for this claim can be seen by considering the case where the first best action is being implemented by punishing an outcome which becomes more likely when one deviates from the first best action. As the size of the hierarchy gets bigger the probability of using this punishment by mistake becomes very small and therefore one can make the punishment itself very large without incurring significantly implementation losses [see the Appendix for a proof of this claim].

What this makes clear is that the question of which limit to take is a non-trivial one and starting with an infinite hierarchy is misleading.

#### IV

##### Empirical Basis for the Model

We argued before that our model was based on a set of stylized facts derived from Soviet experience, F1-F4. In this section, we will provide some evidence for the claim that these are indeed appropriate stylized facts.

F1, i.e., the existence of ministers is universally recognized and can be found in any textbook description of the Soviet economy (see for example, Gregory & Stuart (1981), Nove (1977)). Fedorenko (1986) reports that there are 50 or so ministers controlling something like 20 million products in the industrial sector alone not taking account of product differences on the basis

of timing and location of deliveries. This supports our claim about the large size of ministries, F2.

F3, i.e., the use of linearly aggregated statistics is equally well established. While there are 72,000 types of ball bearings in the Soviet economy, the central planners' statistics only distinguish between 14 types. So, on average, each ball bearing statistic the central planner uses is the linear aggregate of 5,000 numbers (see Karpov (1972)).<sup>5</sup> In fact, the 20 million or so goods in the Soviet economy are for the purposes of planning aggregated into only about 2,000 aggregate categories (Fedorenko, 1986)<sup>6</sup> and as the Hungarian economist Augustinovics says:

"There is a very simple algorithm to reduce total aggregates of detailed plan information; it is addition [Augustinovics (1975)]."

Finally, stylized fact F4 about the rigidity of the allocation system is also supported by textbook accounts of the Soviet economy (see for example, Nove (1977), p. 43-44).

### Possible Remedies

The aim of this section is to argue that simple remedies are not available since the stylized facts F1 to F4 are closely connected with very fundamental characteristics of a Soviet-type system. We will consider a list of possible remedies and argue why they may not be feasible.

#### 1. Direct control of firms by the central planner:

The problem with this is simply that the amount of information necessary to control all the firms in an economy like the Soviet Union is too vast to be available to any one small group of people and therefore some delegation of control is inevitable.

2. Smaller ministers:

This might help somewhat but again the problem is that ministers are large probably because there are economies of scale in the case of specialized knowledge and therefore it is efficient to have a certain group of specialists control a large number of related industries. Making ministers smaller will be costly in terms of losing these economies of scale.

3. Nonlinear aggregation:

In Appendix B of Banerjee-Spagat (1986) we show that there is a non-linear aggregation procedure which will yield the first best. However, this kind of aggregation requires much more information to implement than linear aggregation. The accountants constructing the aggregates have to be able to distinguish between each type in the product group being aggregated rather than just count the total amount of that product irrespective of the specific type. The costs of changing the aggregation system may therefore be very large.

4. Allowing firms to choose their supplier:

This would reduce the rigidity of the allocation and make a firm less dependent on the unreliable supply of one supplier. However, rigid allocation systems may also have a significant advantage which may prevent their being replaced easily. The source of this advantage lies in the phenomenon Janos Kornai calls the soft budget constraint (Kornai (1979 & 1980)). According to Kornai, firms in the centrally planned economies behave as if they face no binding budget constraint. In the face of a perception of scarcity of input supplies, firm managers try to stock up with as many inputs as possible without considering the cost, knowing their costs will be covered by ad hoc subsidies. Since everybody acts in this same way, there is indeed a scarcity

of input supplies and the perception of scarcity is confirmed. This kind of equilibrium with perpetual excess demand is what Kornai calls shortage.

Now, given that this kind of shortage is endemic in centrally planned economies, firms will want to take in all the inputs they can get their hands on. It may then be rational to restrict the sources of inputs available to individual firms. This is perhaps the basis of the existing rigid allocation system and if it is, the nature of the allocation system may not change easily.

5. Rewarding ministers on the basis of total projects:

This will not work since, given rigid prices and linear technology, total profits are actually a linear function of total output and therefore provides no extra information.

6. Encouraging input receiving firms to take direct action against reliable suppliers:

A court system has been instituted in the Soviet Union with this in mind but as Kroll (1986) documents, it is not much used. Fear of reprisals by the input supplying firms may be part of the explanation. (Spagat (1987) formalizes this line of thought in a game-theoretic model.)

V

Conclusions

The point of this paper was to find an explanation for the extreme unreliability of input supplies found in centrally planned economies. We suggest an explanation based on certain well established characteristics of the planning system and argue that their characteristics may be hard to remove without changing the system drastically.

The main actors in our explanation turn out to be ministries. Our story thus provides a formal basis for the implication of Zaslavaskaya (1983) and



Gorlin (1985) that ministries are too big and too powerful. At a more general level this result also provides some intuition as to why a 3-level hierarchy is qualitatively different from a 2-level hierarchy.

Our analysis also allows us to make some predictions about the structure of the impact of shortage. Specifically our model suggests that the impact of shortage would be most severe in industries where the elasticity of substitution between inputs is low (see Banerjee & Spagat (1987)). The framework developed in this paper can also be used to study other problems. In a companion paper (Banerjee-Spagat (1987)) we use this model to discuss the issue of the productivity growth slowdown in the Soviet Union.

FOOTNOTES

<sup>1</sup>See Kornai (1980), Levine (1966) and Davis & Charemza (forthcoming).

<sup>2</sup>See Holzman (1970) and Hunter (1961) for early studies.

<sup>3</sup>For excellent descriptions of the institutional features of the Soviet economy, see Nove (1977) and Gregory and Stuart (1981).

<sup>4</sup>See Banerjee & Spagat (1986).

<sup>5</sup>The notion that ministries are evaluated according to linear aggregates is implicit in Linz (1986) and Berliner (1983). It is more explicit in Grossman (1960).

<sup>6</sup>See Kornai (1957) and Nove (1958) for early analyses of the problem of aggregation.

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## Appendix

One assumption that we see as being crucial is the assumption of bounded punishment. It is easy to see where this assumption is necessary for our results. What is more interesting however is that while in our model in general the larger the size of the hierarchy the more difficult it gets to reach the first best, with unbounded punishments a larger hierarchy may actually bring us closer to the first best.

The intuition of this result comes from an observation of Mirrless (1974) to the effect that if suboptimal actions generate output distributions with a left tail weight that is very high relative to the left tail weight of the distribution generated by the optimal action then an approximate first best can be implemented by inflicting very large punishments on agents with very low outputs. A version of this Mirrlees condition can arise naturally in large hierarchies as we show in the next theorem.

**Theorem 4** - Suppose there is no bound on how much a minister can be punished. Consider a finite action space  $A$  with an optimal action  $a^*$  for the Central Planner. Suppose that for each  $a \in A$ ,  $\tilde{X}(a)$  has a continuous density  $f(x,a)$  with support on  $[0,1]$ . If  $f(0,a) > f(0,a^*)$  for every  $a \neq a^*$  then a first best can be approximated arbitrarily closely for large enough  $M$ .

**Proof** - Claim: For each  $\epsilon > 0$  there exists  $M(\epsilon)$  and  $\bar{X}$  such that  $M > M(\epsilon)$  implies

$$(1) \quad \frac{P\left\{ \sum_{m=1}^M \tilde{X}_m(a) < \bar{X} \right\}}{P\left\{ \sum_{m=1}^M \tilde{X}_m(a^*) < \bar{X} \right\}} > \frac{f(0,a)^M}{f(0,a^*)^M} - \epsilon.$$



This is because,

$$(2) \quad P\left\{ \sum_{m=1}^M \tilde{X}_m(a) < \bar{X} \right\} = \int_0^{\bar{M}\bar{X}} \int_0^{\bar{M}\bar{X}-X_1} \dots \int_0^{\bar{M}\bar{X}} - \sum_{m=1}^M X_m dF(X_1, a) \dots dF(X_M, a)$$

but for  $\bar{M}\bar{X}$  near zero, the right hand side of (2) is approximately,

$$\frac{f(0, a)^M (\bar{M}\bar{X})^M}{M!} \text{ for any } a \text{ so the left hand side of (1) does indeed go to infinity}$$

as  $n \rightarrow \infty$  at the rate indicated.

This result allows us to choose a sequence of punishment utilities

$$\{q_M\}_{M=1}^{\infty} \text{ such that } q_M \cdot P\left\{ \sum_{m=1}^M \tilde{X}_m(a^*) < \bar{X}_M \right\} \rightarrow 0$$

$$\text{and } q_M \cdot P\left\{ \sum_{m=1}^M \tilde{X}_m(a) < \bar{X}_M \right\} \rightarrow \infty$$

for each  $a \neq a^*$ . For example, choose  $\bar{X}_M$  decreasing to zero and set

$$q_M = -M/P\left\{ \sum_{m=1}^M \tilde{X}_m(a) < \bar{X}_M \right\}. \text{ So for large } M \text{ the incentive scheme}$$

$$h(R_M(\sum_{m=1}^M X_m)) = \bar{h} \text{ if } \sum_{m=1}^M X_m < \bar{X}_M$$

$$= q_M \text{ otherwise}$$

will enforce an approximate first best.  $\Delta$

To make the intuition of this result clear consider a case where the minister has two actions.  $\tilde{X}(a^*)$  is zero with probability  $\frac{1}{4}$  and one with probability  $\frac{3}{4}$ .  $\tilde{X}(a)$  is zero with probability  $\frac{1}{2}$  and two with probability  $\frac{1}{2}$ .

Then

$$\frac{P\left\{\sum_{m=1}^M \tilde{X}_m(a) = 0\right\}}{P\left\{\sum_{m=1}^M \tilde{X}_m(a^*) = 0\right\}} = \frac{\left(\frac{1}{2}\right)^M}{\left(\frac{1}{4}\right)^M}.$$

We can set  $q_M = -M(2^M)$  and  $\bar{X}_M = 0$  and enforce an approximate first best.











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